# GROWTH OF PLANTS IN ARTIFICIAL LIGHT

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(WITH TWO FIGURES)

The growth of plants in artificial light has been of interest in plant physiology because it offers the possibility of controlling the quality and intensity of the light, and the duration of the exposure. No reliance can be placed upon sunlight, and its quality and intensity vary greatly. The writer attacked the problem of growing plants in artificial light to gain some idea of the relation of light intensity to the formation and equilibrium concentrations of the carbohydrates formed in leaves, and to the translocation of these substances in light and darkness.

The problem of producing plants in artificial light is of some economic interest in Minnesota and other such localities, where the sunlight is of short duration and low intensity in winter. It is difficult to raise plants in the greenhouse in winter in this latitude when the sun is at a low angle. Some analyses made on cabbage leaves grown in a greenhouse at the University of Minnesota in the winter of 1920 show a practical absence of sugars from the leaves. Very little growth is produced under such conditions; the plants are weak and easily attacked by fungi.

The ability to grow plants in this climate by substituting artificial light for sunlight, or by using artificial light to supplement sunlight on dark days, will be of considerable value for plant breeders. The progeny of valuable crosses can be carried through one or more generations during the winter, and thereby decrease the time required to produce a new strain. In breeding for rust resistance at Minnesota it has been found difficult to carry biological forms of black stem rust of wheat in culture during winter, owing to the weakness of the host plants.

The writer has succeeded in raising a great variety of plants from seed to maturity, using artificial illumination entirely. Light was obtained from nitrogen-filled tungsten filament (Mazda) lamps. The lamps were mounted on the ceiling of basement rooms about five feet from the plants. Ordinary enamelled reflectors of the deep bowl type were used to throw the light downward. The lamps used were of the 200 watt and 1000 watt sizes; the latter is considerably more economical in operation than the smaller size. These lamps are rated to burn 1000 hours, but average about 3000 hours. They were burned twenty-four hours per day, so that one set of lamps was sufficient for four months or more. Breakage of the lamps occurred the most frequently when the current was turned off and the filaments allowed to cool. The continuous burning seemed to greatly increase the life of the lamps.

Plants grew well, set good seed or produced tubers in the continuous illumination. It seems unnecessary to have a period of darkness to allow translocation of the assimilate from the leaves. Several intensities of light were used and the plants grew in each. The lowest intensities of about 25 foot candles in dark corners produced much better growth than was obtained in the greenhouse during the winter. Analyses of the carbohydrate and protein contents of the plants are being made.

In one room $8\times 11$ feet a great variety of cereals was grown, including twenty varieties of wheat, fifteen varieties of oats, eighteen varieties of barley, eight varieties of rye, six varieties of flax, several hybrids of wheat and of oats, and a few other test plants. The room was lighted by lamps with a total capacity of 3200 watts and distributed uniformly. The lamps required about 0.6 watt to produce one spherical candle. Then $\frac{4\,\pi\times 3200}{0.6}=67{,}021$ lumens total flux. On account of the light absorption and inefficiency of the reflectors, only about 60 per cent of this light reaches the ground, so that there are 40,212 lumens spread over the area $8\times 11$ feet, giving an intensity of about 457 lumens per square foot. In this light winter rye headed at about 24 inches; Kota wheat at 28 inches; Bluestem wheat at 23 inches; Aurora oats at 17 inches; Manchuria barley at 17 inches. These plants were grown in 5-inch pots. Usually six or eight kernels were all that set in a head of wheat, but these were plump and full of starch. The temperature was maintained automatically at about 14° C. by cooling with outside air. It was unnecessary to use any heat in this room other than that produced by the lights. The light is doubly efficient, for all that is not used by the plants goes to heat. Since sunlight is not required, the rooms can be insulated much better against heat loss than a greenhouse.

In a room 6×11 feet, lighted by 10–200 watt lamps, several vegetables were grown. The temperature was about 25°–30° C., not well controlled. The light intensity was about 380 lumens per square foot. Potatoes and tomatoes grew well, but were somewhat taller than normal. Early Ohio potatoes bloomed when the vines

FIG. 1.—Cabbage, lettuce, potato, tomato, beans, peas, and a number of other plants growing in continuous artificial light; room 6×8 feet, lighted with lamps of 2600 watts capacity.

were 44 inches long. Boston marrow squash bloomed at 42 inches, but did not set fruit. Alaska peas bloomed at 18 inches and set good seed. *Solanum niger* set abundant fruit, beginning at 6 inches, and continued fruiting up to 28 inches. Cabbage started heads at about 18 inches and showed some effects of etiolation. Buckwheat set normal seed at 20 inches.

In another room 6×8 feet, lighted by lamps with a total capacity of 2600 watts, the plants appeared much more normal than in the room just mentioned (fig. 1). The light intensity here was about 680 lumens per square foot and the temperature 25°–30° C. Cabbage headed at 12 inches; lettuce set abundant seed when 36 inches high. Black wax beans set pods at 35 inches; potatoes (Early Ohio)

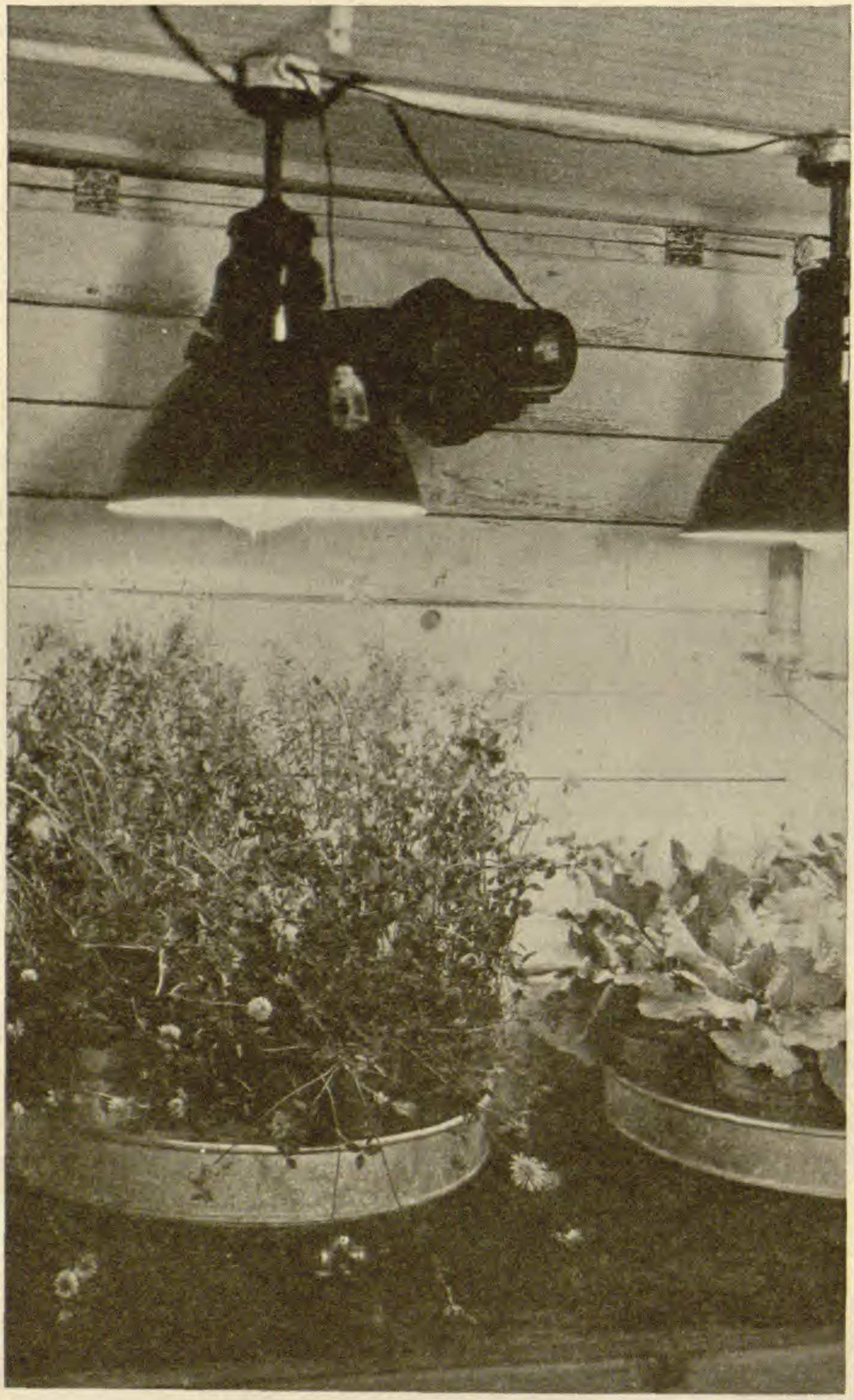

FIG. 2.—Rotating tables operated by electric phonograph motor to equalize light and temperature.

bloomed at 48 inches, and set tubers weighing as high as 180 gm. each. White sweet clover set some seed when 40 inches high. A number of weeds were allowed to grow, and they all set abundant seed. *Boltonia asteroides* bloomed when 54 inches high; *Chenopodium ambrosioides* set seeds profusely at 35 inches; *Silene latifolia* bloomed at 16 inches but did not set seed; *Stellaria media* bloomed and set seed at 16 inches; foxtail grass (*Alopecurus*) set abundant seed at normal height.

Under the 1000 watt lamp shown in fig. 2 the light intensity was about 4188 lumens per square foot. Plants under this light were very stocky, and showed effects of too much heat. The leaves of cabbage were very turgid and stiff. The plants were rotated to equalize light and temperature, and to decrease the heating effect of the light on surfaces directly exposed.

All of the plants in these rooms except cabbage bloomed, and many produced good seed, although the illumination was continuous. It seems then that the period of illumination is not the factor which determines whether a plant will bloom or not. The results obtained by GARNER and ALLARD[1] may have been produced by a modification of the conditions of nutrition of their plants by variation in the length of the day. It is possible to obtain seed from a great variety of plants as here shown, although the illumination is continuous, and the intensity is approximately the same for all plants in one room.

## Summary

A great variety of plants, including wheat, oats, barley, rye, flax, buckwheat, white sweet clover, peas, beans, lettuce, and a number of common weeds were grown from seed to maturity in continuous artificial light, and all set good seed. Potatoes, tomatoes, red clover, alsike clover, squash, and *Silene* bloomed, but did not set seed. Potatoes produced tubers of good size. All of the plants tested did not require a certain period of illumination to cause them to bloom. It is possible to produce seed from plants in winter independent of sunlight, and at no very great expense.

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[1] GARNER, W. W., and ALLARD, H. A., Jour. Agric. Res. 18:553–606. 1920.